CLAIMS

1. A spring structure formed on a substrate made from a first material and having a first surface, the spring structure comprising:

a post formed from a second material and extending from the first surface of the substrate, the post having an upper surface that is displaced from the first surface of the substrate by a predetermined distance;

a spring metal finger having an anchor portion attached to the upper surface of the post such that the anchor portion is separated from the first surface of the substrate by the predetermined distance, the spring metal finger also having a free portion extending over the substrate, the free portion having opposing first and second surfaces; and

a plated metal layer formed on both of the first and second surfaces of the free portion of the spring metal finger;

wherein the plated metal layer has a thickness that is smaller than the predetermined distance.

2. The spring structure according to Claim 1, wherein the predetermined distance is greater than two times larger than the thickness of the plated metal layer.

3. The spring structure according to Claim 1, wherein the post comprises at least one of copper and nickel.

4. The spring structure according to Claim 1, wherein the plated metal layer includes a curved portion extending from the first surface of the substrate to the free portion of the spring metal finger.

5. The spring structure according to Claim 1, further comprising a plating electrode formed between the post and the spring metal finger.

6. The spring structure according to Claim 1, further comprising a release material layer formed between the upper surface of the post and the anchor portion of the spring metal finger.

7. The spring structure according to Claim 1, wherein a tip located adjacent to an end of the free portion of the spring metal finger is exposed through the plated metal.

8. The spring structure according to Claim 7, wherein the tip is an out-of-plane structure extending perpendicular to a surface of the spring metal finger.

9. The spring structure according to Claim 1, further comprising a plurality of tips located adjacent to an end of the free portion of the spring metal finger.

10. A method for fabricating a spring structure on a first surface of a substrate, the method comprising:

forming a base layer over a first surface of the substrate, the base layer having a planarized upper surface that is displaced from the first surface of the substrate by a predetermined distance;

forming a spring metal island on a release material layer, wherein the spring metal island has internal stress variations in the growth direction;

selectively removing a first region of the base layer from beneath a free portion of the spring metal island such

that an anchor portion of the spring metal island remains connected to a post portion of the base layer, where upon removing the first portion of the base layer, the internal stress variations cause the free portion of the spring metal island to bend relative to the substrate, thereby forming a spring metal finger; and

forming a plated metal layer on the free portion of the spring metal finger, wherein the plated metal layer has a thickness that is smaller than the predetermined distance.

11. The method according to Claim 10, wherein forming the base layer comprises forming the post portion using a first material, forming a sacrificial portion surrounding the post portion, and planarizing the post portion and the sacrificial portion.

12. The method according to Claim 10, further comprising forming a release material layer over the base layer before forming the spring metal island.

13. The method according to Claim 10, further comprising:

forming a plating electrode over the base layer before forming the spring metal island; and

applying a predetermined voltage to the plating electrode during formation of the plated metal layer.

14. The method according to Claim 10, further comprising:

forming a plating electrode between the first surface of the substrate and the base layer before forming the spring metal island; and

applying a predetermined voltage to the plating electrode during formation of the plated metal layer.

15. The method according to Claim 10, further comprising forming an out-of-plane tip structure in the base layer before forming the spring metal island, whereby selectively removing the first portion of the base layer causes the out-of-plane tip structure to remain connected to the spring metal finger.

16. The method according to Claim 10, wherein forming the spring metal island comprises forming plurality of tip structures located adjacent to an end of the free portion.

17. A spring structure formed on a substrate having a first surface, the spring structure comprising:

a spring metal finger having an anchor portion attached to the first surface of the substrate, the spring metal finger also having a free portion extending over the substrate; and

a plated metal layer formed on both of the first and second surfaces of the free portion of the spring metal finger;

wherein the substrate defines a trench located below the free portion of the spring metal finger and shaped such that when the free portion of the spring metal finger is deflected toward the substrate, the free portion enters the trench without contacting the first surface of the substrate.

18. The spring structure according to Claim 17, wherein the trench defines a depth, and

wherein the plated metal layer has a thickness that is smaller than the depth of the trench.

19. The spring structure according to Claim 18, wherein the depth is greater than two times larger than the thickness of the plated metal layer.

20. The spring structure according to Claim 16, wherein the plated metal layer includes a curved portion extending from the free portion of the spring metal finger into the trench.

21. The spring structure according to Claim 1, further comprising a release material layer formed between the first surface of the substrate and the anchor portion of the spring metal finger.

22. The spring structure according to Claim 16, wherein a tip located adjacent to an end of the free portion of the spring metal finger is exposed through the plated metal.

23. The spring structure according to Claim 22, wherein the tip is an out-of-plane structure extending perpendicular to a surface of the spring metal finger.

24. The spring structure according to Claim 16, further comprising a plurality of tips located adjacent to an end of the free portion of the spring metal finger.

25. A method for fabricating a spring structure on a first surface of a substrate, the method comprising:

forming a spring metal island over the first surface of the substrate, wherein the spring metal island has internal stress variations in the growth direction;

isotropically etching the substrate in a region located opposite to a free portion of the spring metal island, wherein the internal stress variations cause the free portion of the spring metal island to bend relative to the substrate when the free portion of the spring metal island is separated from the substrate and an anchor portion of the spring metal island remains connected to the substrate, thereby forming a spring metal finger; and

forming a plated metal layer on the spring metal finger.

26. The method according to Claim 25,

wherein isotropically etching the substrate comprises etching the first surface of the substrate such that the trench extends a depth into the substrate, and

wherein the plated metal layer has a thickness that is smaller than the depth of the trench.

27. The method according to Claim 25,

wherein the substrate has a second surface opposite to the first surface, and

wherein isotropically etching the substrate comprises etching through the substrate from the second surface to the first surface.

28. The method according to Claim 25, further comprising:

forming a plating electrode on the first surface of the substrate before forming the spring metal island; and

applying a predetermined voltage to the plating electrode during formation of the plated metal layer.

29. The method according to Claim 25, further comprising forming an out-of-plane tip structure in the first surface of the substrate before forming the spring metal island, whereby isotropically etching the substrate causes the out-of-plane tip structure to remain connected to the spring metal finger.

30. The method according to Claim 25, wherein forming the spring metal island comprises forming plurality of tip structures located adjacent to an end of the free portion.

31. A spring structure formed on a substrate having a first surface, the spring structure comprising:

a spring metal finger including:

an anchor portion attached to the first surface of the substrate,

an intermediate portion extending at a first angle from the anchor portion, the intermediate portion having a first end connected to the anchor portion and a second end located a predetermined distance away from the first surface of the substrate, and

a bent free portion having a first portion extending from the second end of the intermediate portion at a second angle; and

a plated metal layer formed on the free portion of the spring metal finger,

wherein the plated metal layer has a thickness that is smaller than the predetermined distance.

32. The spring structure according to Claim 31, wherein the predetermined distance is greater than two times larger than the thickness of the plated metal layer.

33. The spring structure according to Claim 31, wherein the plated metal layer includes a curved portion extending from the first surface of the substrate along the intermediate portion to the free portion of the spring metal finger.

34. The spring structure according to Claim 1, further comprising a release material layer formed between the first surface of the substrate and the anchor portion of the spring metal finger.

35. The spring structure according to Claim 31, wherein the spring structure further comprises a stress-balancing pad formed on the second end of the intermediate portion and the first end of the free portion, wherein the stress-balancing pad has a second internal stress gradient that is different from the first internal stress gradient.

36. The spring structure according to Claim 35, wherein the anchor portion of the spring metal finger has a first internal stress gradient including compressive layers adjacent the substrate and tensile layers adjacent the stress-balancing pad, and the stress-balancing pad has a second internal stress gradient that is different from the first internal stress gradient.

37. The spring structure according to Claim 35, wherein the first internal stress gradient includes

compressive layers adjacent the substrate and tensile layers adjacent the stress-balancing pad, and wherein the second internal stress gradient includes tensile layers adjacent the compressive layers of the spring metal island, and tensile layers at an upper end of the stress-balancing pad.

38. The spring structure according to Claim 31, wherein a tip located adjacent to an end of the free portion of the spring metal finger is exposed through the plated metal.

39. The spring structure according to Claim 31, wherein a tip located adjacent to an end of the free portion of the spring metal finger includes an out-of-plane structure extending perpendicular to a surface of the spring metal finger.

40. The spring structure according to Claim 31, further comprising a plurality of tips located adjacent to an end of the free portion of the spring metal finger.

41. A method for fabricating a spring structure on a first surface of a substrate, the method comprising:

forming a sacrificial layer over a first surface of the substrate, the sacrificial layer having a planarized upper surface that is displaced from the first surface of the substrate by a predetermined distance, the sacrificial layer also having tapered edge extending downward at a first angle from the upper surface to an exposed portion of the first surface of the substrate;

forming a spring metal island having an anchor portion located over the exposed portion of the first surface, a free

portion formed on the planarized upper surface of the sacrificial layer, and an intermediate portion formed on the tapered edge of the sacrificial layer and connected between the anchor portion and the free portion, wherein the spring metal island has internal stress variations in the growth direction;

releasing the free portion of the spring metal island and removing the sacrificial layer from beneath the free portion such that the anchor portion of the spring metal island remains connected to the substrate, and the internal stress variations cause the free portion of the spring metal island to bend relative to the substrate, thereby forming a spring metal finger; and

forming a plated metal layer on the free portion of the spring metal finger, wherein the plated metal layer has a thickness that is smaller than the predetermined distance.

42. The method according to Claim 41, further comprising:

forming a plating electrode on the first surface of the substrate before forming the spring metal island; and

applying a predetermined voltage to the plating electrode during formation of the plated metal layer.

43. The method according to Claim 41, further comprising forming an out-of-plane tip structure in the sacrificial layer before forming the spring metal island, whereby etching the sacrificial layer causes the out-of-plane tip structure to remain connected to the spring metal finger.

44. The method according to Claim 41, wherein forming the spring metal island comprises forming a plurality of tip structures located adjacent to an end of the free portion.

45. A method for fabricating a spring structure on a first surface of a substrate, the method comprising:

forming a layered structure including a spring metal finger having a first stress gradient in the growth direction, and a stress-balancing pad formed on the spring metal finger and having a second stress gradient that is different from the first stress gradient, wherein the spring metal finger includes an anchor portion, an intermediate portion having a first end connected to the anchor portion, and a free portion having a fixed end connected to a second end of the anchor portion, and wherein the stress-balancing pad is formed on a section of the spring metal island including the fixed end of the free portion and the second end of the intermediate portion; and

releasing the intermediate portion and the free portion of the spring metal island such that the anchor portion of the spring metal island remains connected to the substrate, and the first stress gradient causes the intermediate portion and the free portion of the spring metal island to bend away from the substrate to form a spring metal finger, wherein the second stress gradient of the stress balancing pad forms a knee at the section of the spring metal island including the fixed end of the free portion and the second end of the intermediate portion, said knee being positioned a predetermined distance above the first surface of the substrate; and

forming a plated metal layer on the free portion of the spring metal finger, wherein the plated metal layer has a thickness that is smaller than the predetermined distance.

46. The method according to Claim 45, wherein forming the layered structure comprises forming the stress-balancing pad using a relatively thick layer of highly compressive material.

47. The method according to Claim 45, wherein forming the layered structure comprises forming the stress-balancing pad such that first layers located adjacent to an upper surface of the spring metal finger are relatively tensile, and second layers located above the first layers are relatively compressive.

48. The method according to Claim 45, further comprising:

forming a plating electrode on the first surface of the substrate before forming the spring metal island; and

applying a predetermined voltage to the plating electrode during formation of the plated metal layer.

49. The method according to Claim 45, further comprising forming an out-of-plane tip structure in the first surface of the substrate before forming the spring metal island, whereby releasing the free portion causes the out-of-plane tip structure to remain connected to the spring metal finger.

50. The method according to Claim 45, wherein forming the spring metal island comprises forming plurality of tip structures located adjacent to an end of the free portion.

51. A spring structure formed on a substrate made from a first material and having a first surface, the spring structure comprising:

a spring metal finger having an anchor portion attached to the substrate, the spring metal finger also having a free portion bending away from the substrate, the free portion having an upper surface facing away from the first surface of the substrate, the spring metal finger also having longitudinal edges; and

a plated metal layer formed only on the first surface of the free portion of the spring metal finger between the first and second edges.

52. The spring structure according to Claim 51, further comprising a non-conductive layer formed on a lower surface of the spring metal finger.

53. The spring structure according to Claim 51, further comprising a plating electrode formed between the first surface of the substrate and the anchor portion of the spring metal finger.

54. The spring structure according to Claim 51, further comprising a release material layer formed between the first surface of the substrate and the anchor portion of the spring metal finger.

55. The spring structure according to Claim 51, wherein a tip located adjacent to an end of the free portion of the spring metal finger is exposed through the plated metal.

56. The spring structure according to Claim 51, wherein a tip located adjacent to an end of the free portion of the spring metal finger includes an out-of-plane structure extending perpendicular to a surface of the spring metal finger.

57. The spring structure according to Claim 51, further comprising a plurality of tips located adjacent to an end of the free portion of the spring metal finger.

58. A method for fabricating a spring structure on a first surface of a substrate, the method comprising:

forming a spring metal island having an internal stress gradient over the first surface of the substrate, the spring metal island having an upper surface facing away from the first surface of the substrate, the spring metal island also having first and second longitudinal edges and a seed material patterned on the upper surface between the first and second longitudinal edges;

releasing a free portion of the spring metal island such that an anchor portion of the spring metal island remains connected to the substrate, and the internal stress gradient causes the free portion of the spring metal island to bend away from the substrate to form a spring metal finger; and

forming a plated metal layer on the upper surface of the spring metal finger, wherein the seed layer is arranged

such that the plated metal layer is only formed on the upper surface.

59. The method according to Claim 58, wherein the spring metal island comprises MoCr, and wherein the seed layer and the plated metal layer comprise gold.

60. The method according to Claim 58, further comprising:

forming a plating electrode between the first surface of the substrate and the base layer before forming the spring metal island; and

applying a predetermined voltage to the plating electrode during formation of the plated metal layer.

61. The method according to Claim 58, further comprising forming an out-of-plane tip structure in the substrate before forming the spring metal island, wherein releasing the free portion causes the out-of-plane tip structure to be pulled out of the substrate.

62. The method according to Claim 58, wherein forming the spring metal island comprises forming a plurality of tip structures located adjacent to an end of the free portion.

63. A method for fabricating a spring structure on a substrate, the method comprising:

forming a spring metal island over the substrate, wherein the spring metal island has internal stress variations in the growth direction;

selectively releasing a free portion of the spring metal island such that the internal stress variations cause

the free portion of the spring metal island to bend relative to the substrate, thereby forming a spring metal finger that is connected to the substrate by an unreleased anchor portion;

forming a resist portion between the free portion of the spring metal finger and the substrate; and

forming a plated metal layer on exposed sections of the free portion of the spring metal finger, wherein the resist portion prevents formation of plated metal on a lower surface of the free portion of the spring metal finger adjacent to the anchor portion.

64. The method of Claim 63, wherein forming the resist portion comprises:

coating the spring metal finger with photoresist material;

exposing the resist using the spring metal finger as a mask to shield the resist portion of the photoresist material located between the spring metal finger and the substrate; and

removing the exposed resist from the spring metal finger, whereby the resist portion is maintained between the spring metal finger and the substrate.

65. The method of Claim 64,

wherein selectively releasing the free portion of the spring metal island comprises forming a release mask over an anchor portion of the spring metal island, and

wherein the method further comprises reflowing the release mask after forming the resist portion and before forming the plated metal layer.

66. The method according to Claim 63, further comprising forming an out-of-plane tip structure in the substrate before forming the spring metal island, wherein releasing the free portion causes the out-of-plane tip structure to be pulled out of the substrate.

67. The method according to Claim 63, wherein forming the spring metal island comprises forming a plurality of tip structures located adjacent to an end of the free portion.